Introducing Engineering and Technology Education in Primary Schools

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The action research study, aimed at developing interest and understanding among primary school students in engineering and technology. Data were collected by administering a modified version of a pre-validated questionnaire 'Engineering is Elementary' (EIE) twice to 340 upper primary school students in a three phase study. In the first phase students' existing understanding about 'What Engineers Do?' and 'What is Technology?" were explored. In the second phase a lecture explaining the relationship between Science, Technology and Engineering was delivered followed by three engineering related student activities. In the third phase the EIE was readministered and significant differences in student understanding were identified in recognition of the items in the EIE suggesting that an intervention programme could play key role in creating students interest in engineering and Technology.

Introduction

Despite massive advances in science, few citizens worldwide are technologically literate, largely because technology and engineering are seldom taught in schools (Lachapelle & Cunningham, 2007). Just as it is important to begin science instruction in primary school by building on children's curiosity about the natural world, it is also important to begin engineering instruction in primary school by building on children's natural inclination to design, build and take things apart (Cunningham & Hester, 2007). At the heart of engineering is an understanding of the engineering design process – a highly flexible method of solving problems. It is essential that young people's interest in science, technology and engineering is stimulated and maintained throughout their schooling so that students continue with studies in these fields at the university level in order to address the skills shortage (MCEETYA, 2006). A community with an understanding of the nature of science and scientific inquiry will be better equipped to participate in an increasingly scientific and technological world (Williams, 2001). Opening young minds to the wonders of the natural world, stimulating curiosity and creative thinking, and starting that journey towards scientific and technological literacy, requires a strong and effective primary school engineering programme.

Science through engineering can be seen in every aspect of the built environment and it is essential to Australia's prosperity, lifestyle and global competitiveness. As Australia moves into the knowledge-based economy, it is vital for Australia's future development that the number of engineering graduates increases. To increase the number of engineers, children must develop an interest in science, engineering and technology throughout their school lives. Accordingly, cultural and curriculum changes within the schooling system need to occur. In Australia while the numbers of students completing Year 12 have increased, the proportion of students interested in studying chemistry, physics and advanced mathematics has declined, and initiatives to address this decline need to be implemented as a matter of urgency (Wogan, 2011).

Research Questions

The overarching aim of this project was to develop interest and understanding through improved learning environments among primary school students in engineering and technology (E & T) as potential career choices in order to redress the problem of insufficient numbers in the pool of locally-trained professionals in these fields. Further, the project aimed at developing the engineering and technology literacy of primary school students and teachers. The objectives of this study are:

- To investigate what activities primary school students classify as being E & T.
- To develop and validate an instrument to assess the primary school students' learning environment and their understanding and interest in E & T.
- To assess the effectiveness of the implemented E & T lessons in terms of the quality of the classroom learning environment and student understanding and interest in E & T.

Theoretical Framework(s)

Learning Environment Research

The study drew upon and contributed to the burgeoning field of learning environments (Fraser, 2007). Contemporary research on school environments partly owes it's inspiration to Lewin's (1936) seminal work in non-educational settings, which recognised that both the environment and its interaction with the characteristics of the individual are potent determinants of human behaviour. Since then, the notion of person-environment fit has been elucidated in education by Stern (1970), and Walberg (1981) has proposed a model of educational productivity in which the educational environment is one of nine determinants of student learning. Over the last four decades, learning environment research has become a firmly established form of research on teaching and learning (Fisher & Khine, 2006).

A hallmark of the field of learning environments is the existence of a variety of economical, robust and extensively validated questionnaires that measure different psychosocial dimensions of the classroom. These instruments are used to investigate the learning environment more closely from the perspective of the students who make up a classroom rather than from the perspective of trained observers or teachers.

One of the most promising applications of classroom environment assessments is their use as process criteria of effectiveness in evaluating educational programmes. For example, when Martin-Dunlop and Fraser (2008) used learning environment criteria in evaluating an innovative science course for prospective American primary teachers, students reported very large gains in classroom open-endedness and material environment between the beginning and end of the course. Similarly, when Nix, Fraser and Ledbetter (2005) evaluated the impact of an innovative teacher development programme based on the Integrated Science Learning Environment (ISLE) model in school classrooms, students whose science teachers had attended the ISLE program perceived more positive learning environments in their classrooms relative to the classrooms of other science and non-science teachers in the same schools. In the proposed study, we also will use learning environment criteria in evaluating the effectiveness of the implemented engineering programme.

Engineering and Technology (E&T) Education

Traditionally engineering has been known as a formal post-secondary discipline and engineering education has focussed on improving the teaching and learning of engineering at the tertiary level (Bagiati & Evangelou, 2011). Despite huge advances in science, few citizens worldwide are technologically literate, largely because E&T is seldom taught in schools (Lachapelle & Cunningham, 2007). Just as it is important to begin science instruction in primary school by building on children's curiosity about the natural world, it is recognised internationally that it is equally important to begin E&T education in primary school by building on children's natural inclination to design, build and take things apart (Andrews & Clark, 2011; Cunningham & Hester, 2007). In Australia, the problems of declining numbers in student preferences in E&T stem from the lack of engagement with science and technology in primary schools (Australian National Engineering Taskforce, 2010). It is highly desirable that young people's interest in both science and E&T is stimulated and maintained throughout schooling so that students choose to continue with studies in these fields at the university level in order to redress the skills shortage (MCEETYA, 2006; Petroski, 2003).

Solomonidou and Tassios (2007) found that Greek children aged 9–12 years tend to think of technology as anything "modern" and have difficulty in thinking about technologies as having any history. Burns (1994) found that New Zealand children aged 12–13 years have ill-defined concepts of technology, whereas DeVries (1996) found that young adolescent children in the Netherlands view technology as a collection of products, particularly "high-tech" products, and show no awareness of technological processes. Lachapelle and Cunningham (2007) found that primary-school children in the USA tend to think of technology as anything modern or anything powered by electricity and think of engineers as people who repair things such as cars or who construct buildings and bridges. The compelling evidence above motivated us to propose this research programme.

High-quality teaching of science in Australian primary schools is a national priority in order to develop citizens who are scientifically literate, can contribute to the social and economic well-being of Australia, and achieve their own potential (Goodrum & Rennie, 2007). Opening young minds to the wonders of the natural world, stimulating curiosity and creative thinking, and starting that journey towards scientific and technological literacy require a strong and effective primary-school E&T programme that promotes positive learning environments and student interest and understanding in E&T.

Methodology

The initial study involved 340 students from 15 primary classrooms in five schools in years 4, 5 and 6. A survey instrument by Lachapelle and Cunningham (2007) was modified and implemented to assess these students' understanding and interest in E & T. After the survey a lesson defining engineering and the importance of Science, Engineering and Technology was delivered to these classes by the first author who is an engineer by training.

In addition at least one engineering topic (two to three lessons), chosen by the class teachers was taught in these classes. The topics taught were in the area of (i) oil spill solutions (ii) electricity (iii) earthquakes (iv) natural and processed materials (v) energy and change and (vi) human biology. Researchers used lesson plans from Tryengineering (www.tryengineering.org) as a guideline and modified them to fit local needs. Teachers were given the lesson plans, materials and any other support they needed for these lessons. These lessons were observed by at least one researcher. A post-test survey was administered to these students to find any changes in understanding and interest in E & T. Table 1 represents the demographic information about the participating students in the study.

School	Student No	Cohort (%)
1	67	19.7
2	77	22.6
3	69	20.3
4	54	15.9
5	73	21.5

Year	Student No	Cohort (%)
4	126	37.1
5	120	35.3
6	94	27.6

Parent engineer	Student No	Cohort (%)
Yes	33	9.7
No	307	90.3

Gender	Student No	Cohort (%)
Boys	147	43.2
Girls	193	56.8

Table 1. Demographic information about the sample

Findings

Validation

The validity and reliability information of the instrument used in this study was determined by the degree to which items in the same scale measure the same aspect of interest and understanding of E & T, a measure of internal consistency, the Cronbach alpha reliability coefficient (Cronbach, 1951) was used. The alpha reliability of 0.71 was obtained for the scales of 'What Engineers Do' and 0.63 for the scale of 'What is Technology'. Both the scale reliabilities are above 0.5 making the instrument reliable for use.

Perception of Engineering and Technology

The survey probed children's perception of engineering and technology, asking them 'What does an engineer do?' and 'What is technology?', to draw examples of what an engineer does and what is technology, and to describe their pictures in words. The results indicated that students generally had a poor idea about the type of work engineers do while more than 60% students had sound understanding about technology. Very few students wanted to take up engineering related careers, however, there was an increase in student career aspirations as well as understanding of engineering and technology in the post-test results. Details of the results can be seen in Table 2.

In order to more systematically probe student's perceptions of E & T, the questionnaire included both captioned images of working people from which the students had to choose those that showed what an engineer would be expected to do at work, and other captioned images of items that may or may not represent technology while asking students, "What is technology?" In both tests the students showed a significant shift towards selection of correct responses between the pre-test and post-test results (please see Tables 3 and 4). As part of our evaluation of the E & T teaching, we examined the pre-test/post-test changes in students' perceptions that occurred during the instruction. Each wrong answer was marked as zero and right as one. The magnitude of each pre-test/post-test difference is described in Tables 3 and 4, in terms of effect size (i.e. the number of standard deviations), whereas a t-test for paired samples was used to determine the statistical significance of this difference.

	Pre-test		**Post-test**
	Student No	**Percentage**	**Student No**
Work aspiration (What would you like to be when you grow up?)			
Engineering	26	7.6	35
Non engineering	314	92.4	260
No response			45
Engineering brainstorm (What does an engineer do?)			
No idea	9	2.6	2
Poor idea	170	50	10
Moderate idea	65	19.1	96
Sound idea	96	28.2	232
Technology brainstorm (What is technology?)			
No idea	11	3.2	3
Poor idea	20	5.9	4
Moderate idea	104	30.6	32
Sound idea	205	60.3	301

Table 2. Student work aspirations and understanding of Engineering and Technology

Item	**Item mean**		**Item SD**		**Differences**
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Effect size**
Design circuits	0.69	0.87	0.46	0.34	0.44
Make better food	0.02	0.09	0.13	0.29	0.32
Design machines	0.75	0.96	0.43	0.21	0.68
Better farming	0.15	0.37	0.35	0.48	0.52
Design better phones	0.46	0.82	0.49	0.38	0.82
Design MRI	0.44	0.78	0.49	0.41	0.77
Design tablets	0.04	0.54	0.21	0.51	1.32
Protect coastline	0.13	0.32	0.34	0.47	0.47
Work as a team	0.57	0.83	0.49	0.38	0.59
Make smaller recorders	0.31	0.67	0.46	0.47	0.77
Design bridges	0.56	0.90	0.49	0.30	0.83

Item	Item mean		Item SD		Differences
Design space shutters	0.49	0.79	0.50	0.41	0.66
Work as electrician	0.39	0.35	0.49	0.48	0.08
Build houses	0.59	0.48	0.49	0.50	0.22
Drive machines	0.69	0.73	0.46	0.44	0.08
Repair machines	0.20	0.27	0.40	0.45	0.16

Table 3. Item Mean and Standard Deviation for Pre-Post tests in Students' Perceptions on the items in the Engineering Questionnaire

Effect Size, in terms of the differences in means divided by the pooled standard deviation ranged between 0.08 to 1.32 standard deviations for the engineering test and 0.06 to 0.98 standard deviations for the technology test. The effect sizes for the engineering questions were larger for most scales.

The engineering test recorded statistically significant changes in all items pre-test/post-test differences except for the item of 'work as electrician' and 'drive machine'. Similarly only three items demonstrated insignificant changes in pre-test/post-test differences in the technology test.

Item	Item mean		Item SD		Differences
	Pre-test	Post-test	Pre-test	Post-test	Effect size
TV	0.96	0.98	0.19	0.13	0.12
Train	0.76	0.89	0.43	0.65	0.23
Running shoes	0.09	0.49	0.29	0.50	0.98
Telephone	0.94	0.97	0.24	0.17	0.14
Tea cup	0.05	0.12	0.21	0.33	0.25
Manufacturing plant	0.62	0.78	0.49	0.41	0.35
Refinery	0.54	0.75	0.49	0.43	0.45
Computer	0.97	0.98	0.16	0.13	0.06
Bicycle	0.14	0.34	0.35	0.47	0.48
Bridge	0.13	0.42	0.34	0.49	0.69
Genetics (artificial arm)	0.31	0.47	0.46	0.50	0.33
Spaceship	0.83	0.90	0.37	0.31	0.20
Tree	0.98	0.96	0.13	0.19	0.12
Bird	0.99	0.97	0.12	0.16	0.14
Lightening	0.76	0.64	0.43	0.48	0.26
Ecosystem	0.89	0.80	0.32	0.39	0.25

Table 4. Item Mean and Standard Deviation for Pre-Post test in Students' Perceptions on the items in the Technology Questionnaire

Qualitative data

After running E & T lessons informal interviews were conducted with participating teachers and students. Denzin and Lincolin, (1994) bricolage method influenced the research team while interpreting the information, which was collected using a variety of research methods. This approach enabled the team to draw on a variety of paradigms for their interpretation in a bid to explain the cultural, factors that could contribute towards the student understanding and interest in E & T. Qualitative data further strengthened our claim. Teachers recognised the need for E & T education and longed for support. Both students and teachers felt that it is imperative for a safe future for Australia that E & T education should be imparted to primary students. The main points, which emerged from the teacher and student interviews, are:

- Expert Support
- Resources-Material to Teach, Resource Book and Resources for student site visits

Conclusions

The results of this pilot study have demonstrated that at the time of the pre-test students had a fair understanding of what technology meant and generally very poor understanding of what engineers do. Students and teachers enjoyed the E & T lessons and statistically significant differences were recorded in students understanding in the post-test. Further work is continuing to incorporate research, evaluation and assessment into all aspects of curriculum design and testing from its inception. Our research questions, assessment instruments and curriculum continue to evolve.

Recommendations and future research plans

There will be a continuing effort to run similar projects for primary and secondary school students. This effort needs to be strengthened by professional development of teachers and a unit on engineering education in teacher education programmes.

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